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Wireless Control That Simply Works

Applications of ZigBee Technology

NIST October 7, 2005
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TUV Rheinland Group
Wireless Business Development
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Wireless Control That Simply Works

- Primer on ZigBee technology and its applications
  - Provide general understanding of ZigBee
    - Technology
  - Understand the vocabulary of ZigBee
  - General idea about how ZigBee devices are constructed and used
  - Relevant Regulatory Issues

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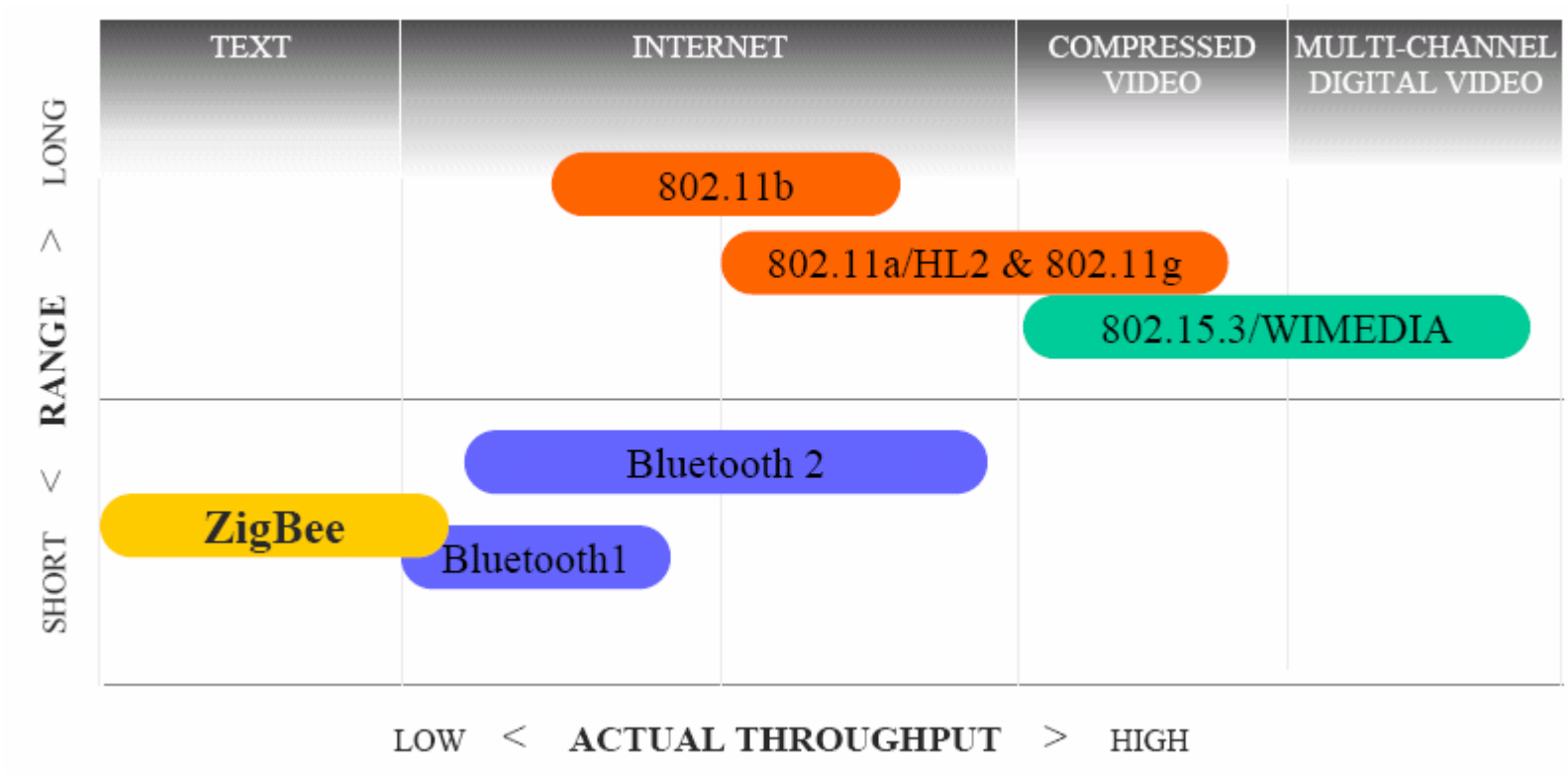

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Feature(s)	IEEE 802.11b	Bluetooth	IEEE 802.15.4
Power Profile	Hours	1 Week	1Year+
BOM	$9	$6	$3
Complexity	Complex	Very Complex	Simple
Nodes/Master	32	7	64000
Latency	Enumeration upto 3 seconds	Enumeration upto 10 seconds	Enumeration 30ms
Range	100 m	10m	70m
Extendability	Roaming possible	No	YES
Data Rate	11Mbps	1Mbps	250Kbps
Security	Authentication Service Set ID (SSID)	64 bit, 128 bit	128 bit AES and Application Layer user defined

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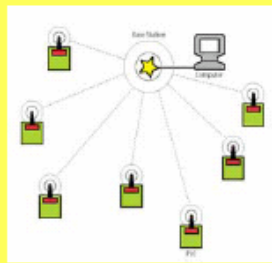
Point to Point

- Simple wire replacement
- Direct Connection between devices
- Limited communication

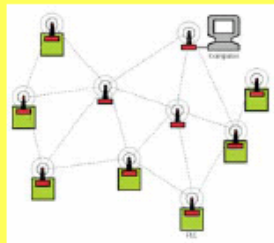
Point to Multi-Point

- Centralized routing and control point
- Examples include: Wi-Fi, GSM, Bluetooth
- All data must flow through "base station"



Multi-hop/Mesh

- Full RF redundancy, with multiple data paths
- Self Configuring / Self Healing
- Distributed Intelligence



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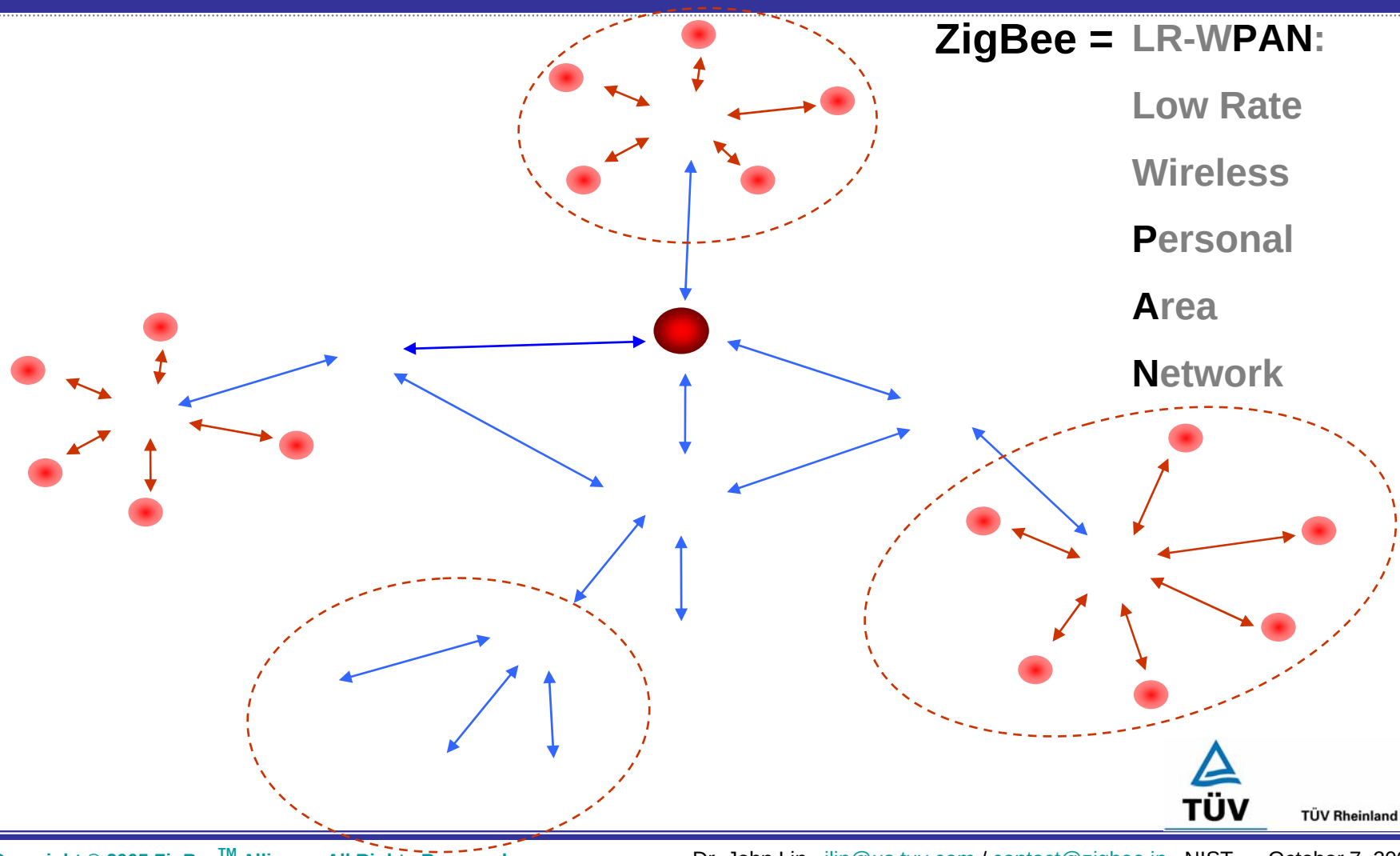

ZigBee = LR-WPAN:

Low Rate

Wireless

Personal

Area

Network

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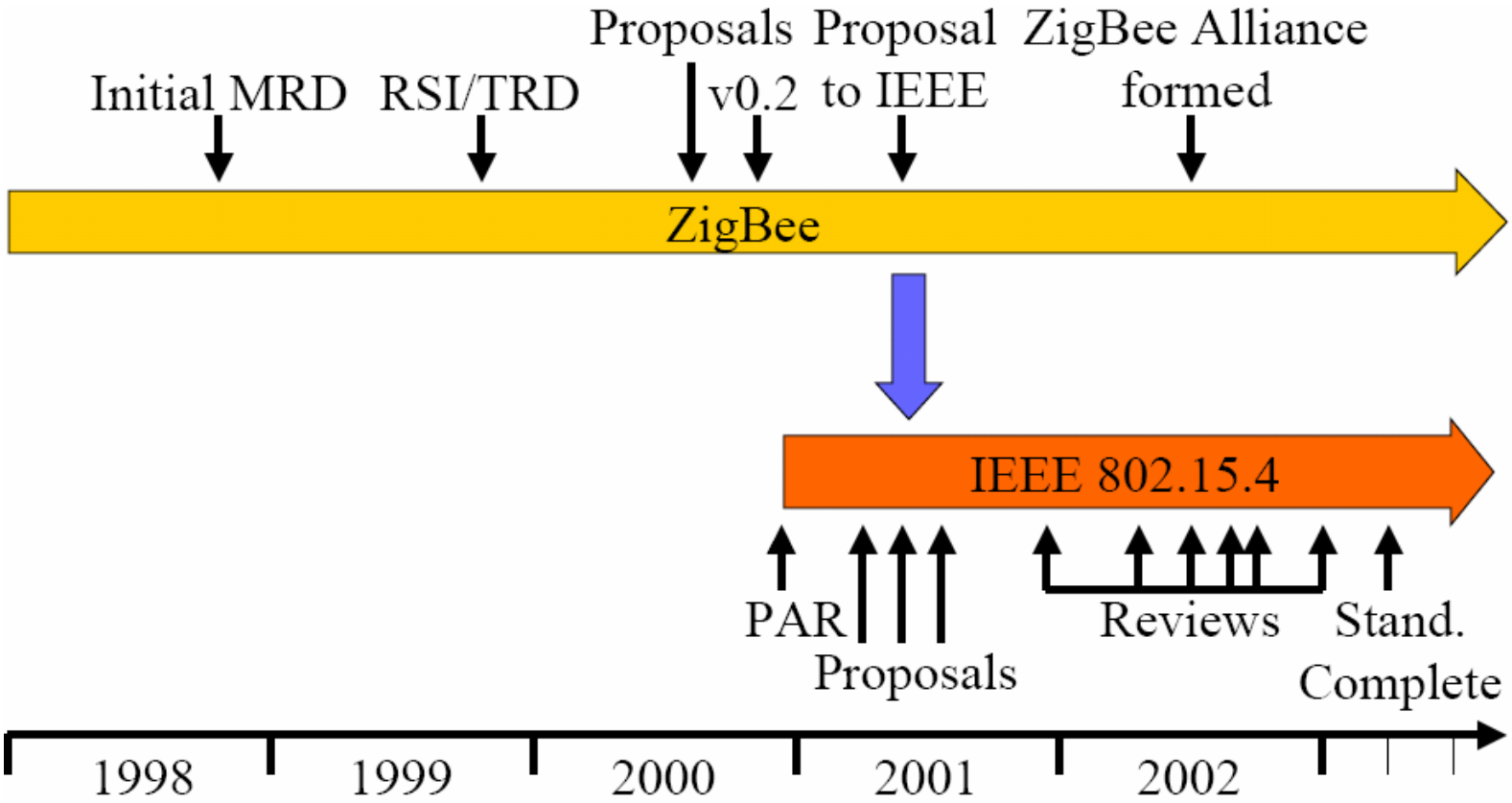

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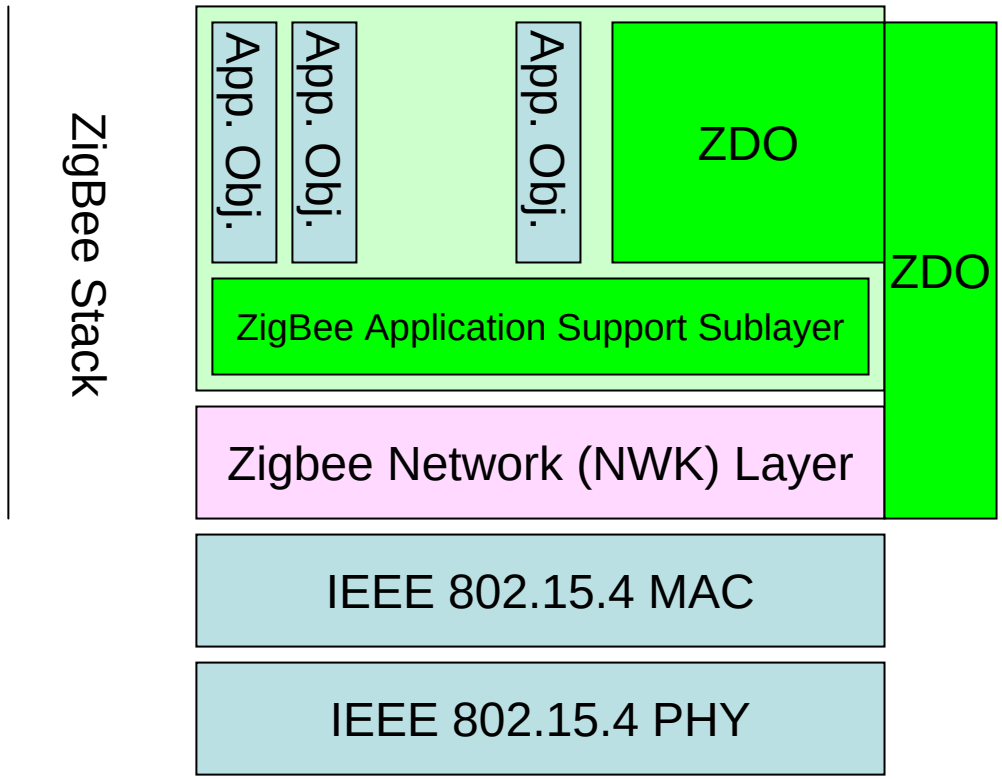

Level 3

Level 2

Level 1

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IEEE 802.15.4 Radio

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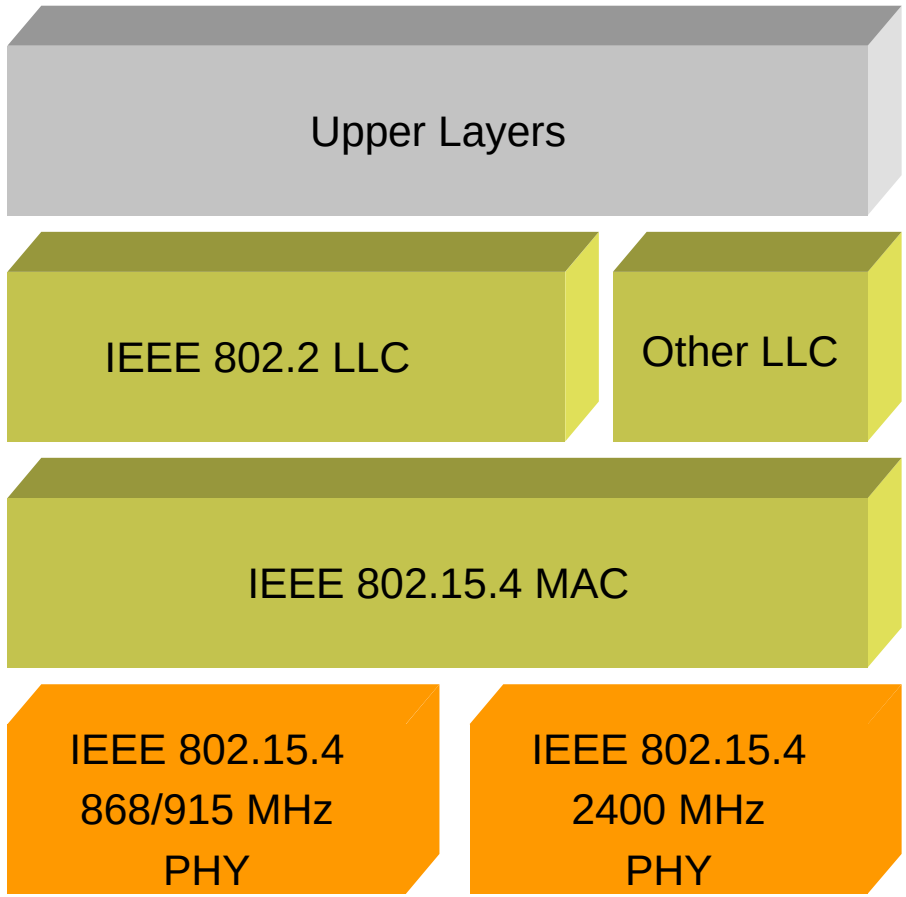

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- Data rates of 250 kb/s, 40 kb/s and 20 kb/s.
- Star or Peer-to-Peer operation.
- Support for low latency devices.
- CSMA-CA channel access.
- Dynamic device addressing.
- Fully handshaked protocol for transfer reliability.
- Low power consumption.
- Frequency Bands of Operation, either:
  - ✓16 channels in the 2.4GHz ISM band;
  - ✓Or 10 channels in the 915MHz ISM band and 1 channel in the European 868MHz band.

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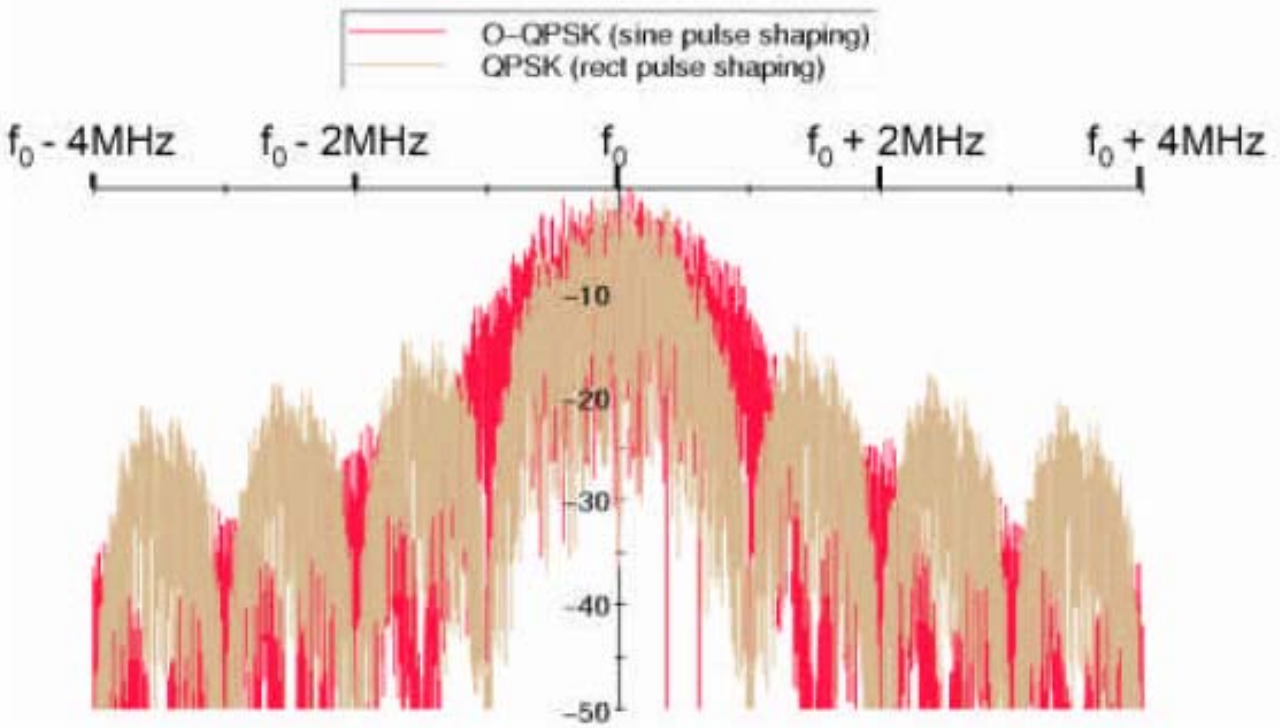

Fig 1: Frequency behaviour of IEEE802.15.4 in the 2.4 GHz-ISM-band (courtesy oi Freescale [5])

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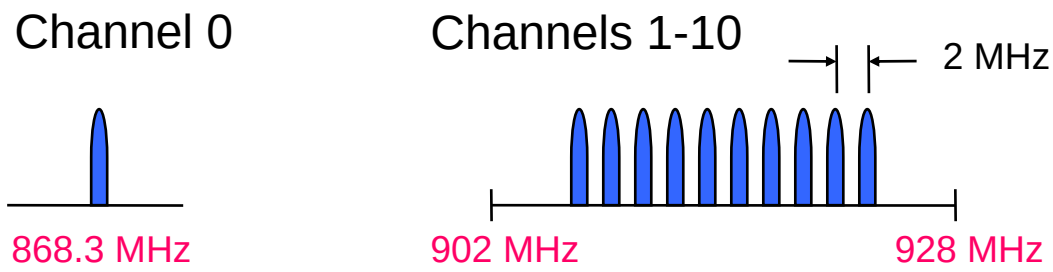
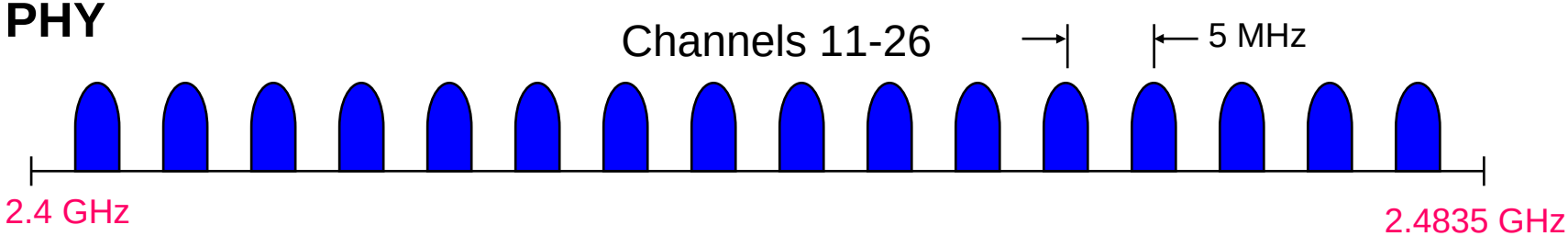
868MHz / 915MHz PHY



2.4 GHz PHY



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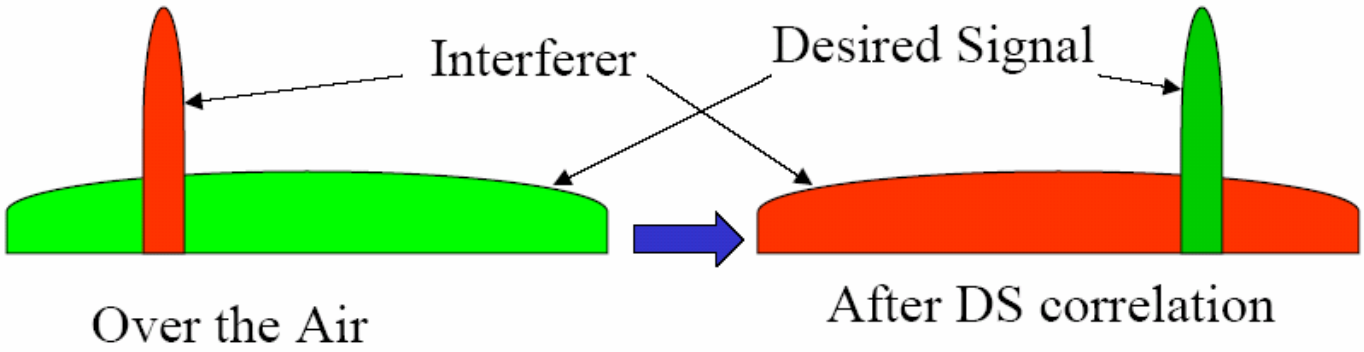

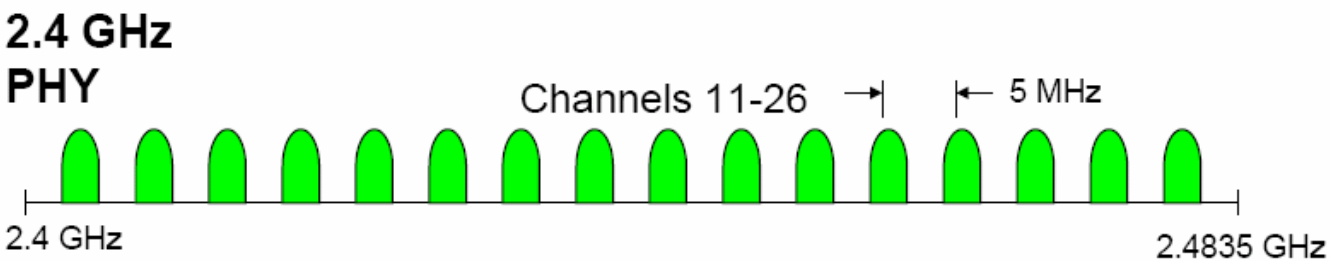

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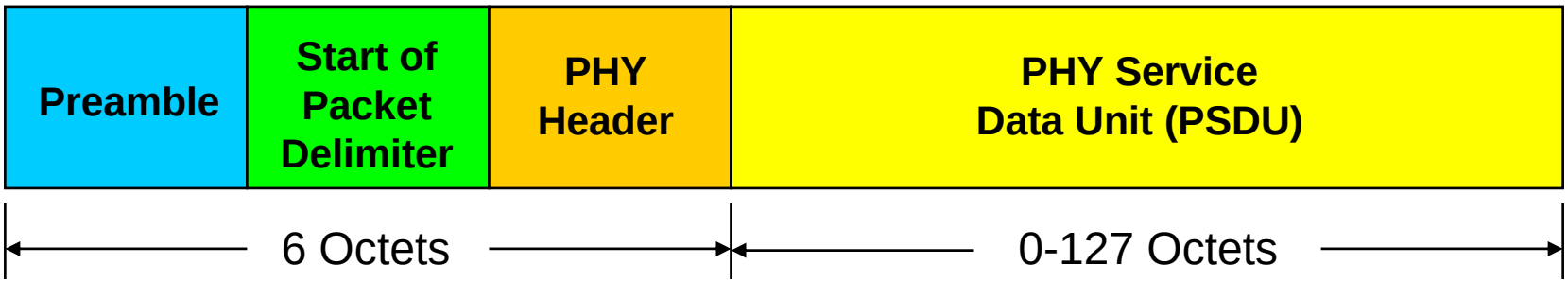
PHY Packet Fields

- Preamble (32 bits) – synchronization
- Start of Packet Delimiter (8 bits)
- PHY Header (8 bits) – PSDU length
- PSDU (0 to 1016 bits) – Data field



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2.4 GHz PHY

- 250 kb/s (4 bits/symbol, 62.5 ksymbols/s)
- Data modulation is 16-ary orthogonal modulation
- 16 symbols are orthogonal set of 32-chip PN codes
- Chip modulation is O-QPSK at 2.0 Mchips/s

868MHz/915MHz PHY

- Symbol Rate
  - 868 MHz Band: 20 kb/s (1 bit/symbol, 20 ksymbols/s)
  - 915 MHz Band: 40 kb/s (1 bit/symbol, 40 ksymbols/s)
- Data modulation is BPSK with differential encoding
- Spreading code is a 15-chip m-sequence
- Chip modulation is BPSK at
  - 868 MHz Band: 300 kchips/s
  - 915 MHz Band: 600 kchips/s

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Transmit Power
- Capable of at least .5 mW

Transmit Center Frequency Tolerance
- ± 40 ppm

Receiver Sensitivity (Packet Error Rate <1%)
- ≤-85 dBm @ 2.4 GHz band
- ≤-92 dBm @ 868/915 MHz band

Rx Signal Strength Indication Measurements
- Packet strength indication
- Clear channel assessment
- Dynamic channel selection

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- Relevant issues for regulatory testing
  - IEEE 802.15.4 radios
    - May or may not be variable for power output
    - Nominally 0dBm output
    - PCB antennas are the norm
    - Generally have third party lab certification for conformance to IEEE 802.15.4 radio/PHY
    - May or may not have IEEE 802.15.4 MAC

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- Relevant issues for regulatory testing
  - IEEE 802.15.4 radios manufacturers for 2.4GHz
    - Chipcon AS has 60% of the market
    - Freescale Semiconductors radios are common
    - Oki Semiconductor radios are also common
    - Most implementations have integrated radios in a two chip solution, or in a module with integrated microcontroller

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- Relevant issues for regulatory testing
  - IEEE 802.15.4 radios manufacturers for 2.4GHz
    - Currently Norway, US, and Japan
    - Up and coming from England, Korea, and Taiwan
  - IEEE 802.15.4 radios manufacturers for 868/915 MHz
    - Currently Germany and US

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IEEE 802.15.4 Medium ACcess (MAC)

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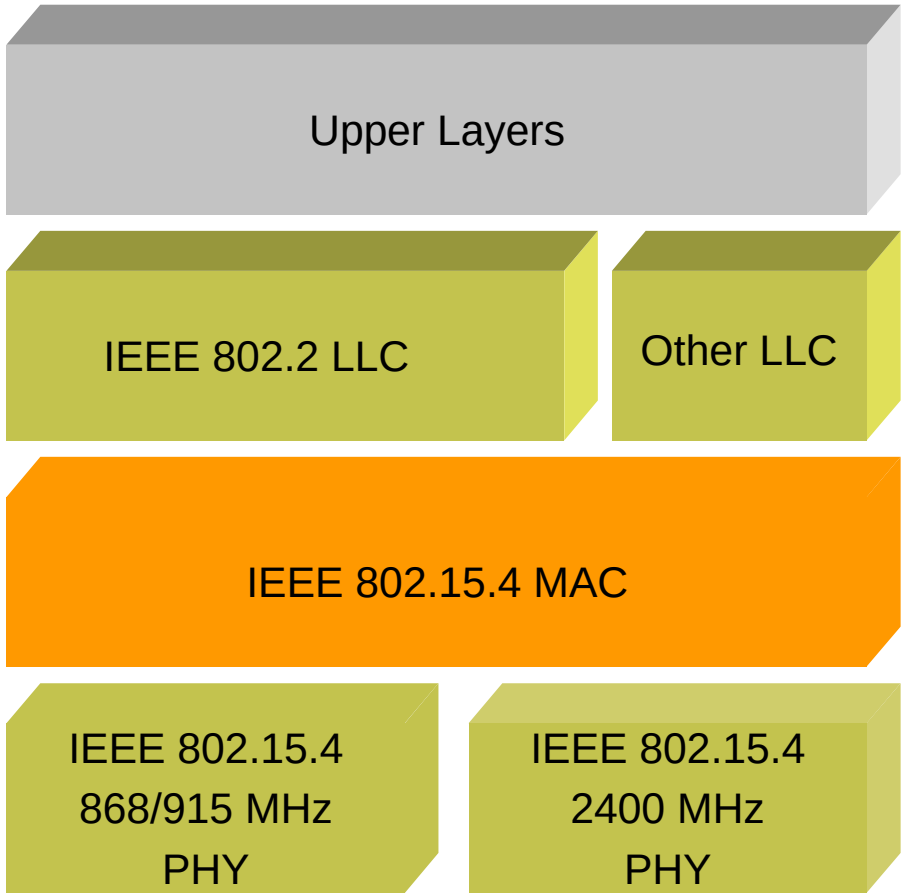

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- Full function device (FFD)
  - Any topology
  - Network coordinator capable
  - Talks to any other device

- Reduced function device (RFD)
  - Limited to star topology
  - Cannot become a network coordinator
  - Talks only to a network coordinator
  - Very simple implementation

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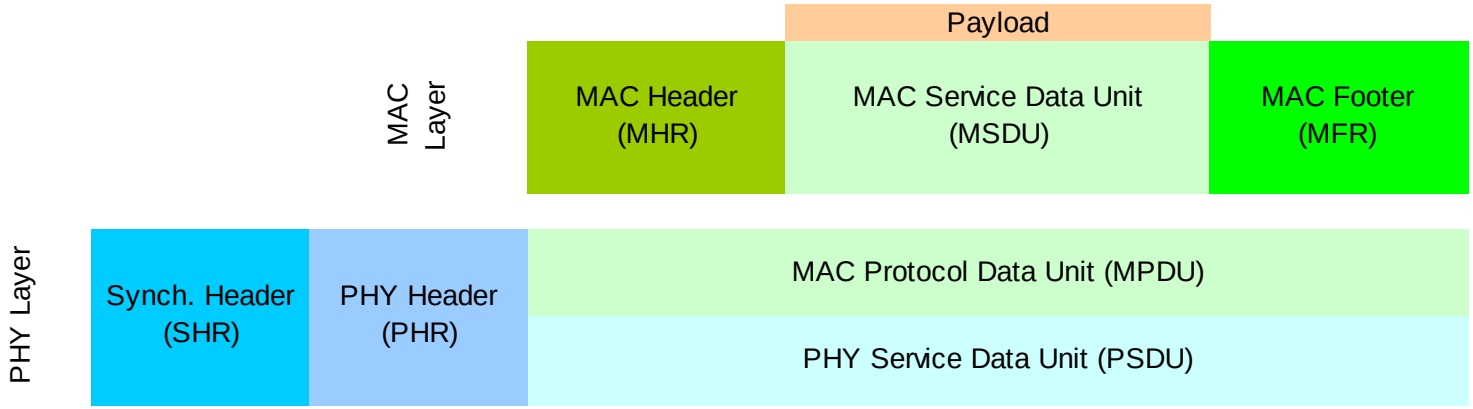

4 Types of MAC Frames:

- Data Frame
- Beacon Frame
- Acknowledgment Frame
- MAC Command Frame

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Command frame identifier	Command name	RFD		Subclause
		Tx	Rx	
0 x 01	Association request	X		7.3.1.1
0 x 02	Association response		X	7.3.1.2
0 x 03	Disassociation notification	X	X	7.3.1.3
0 x 04	Data request	X		7.3.2.1
0 x 05	PAN ID conflict notification	X		7.3.2.2
0 x 06	Orphan notification	X		7.3.2.3
0 x 07	Beacon request			7.3.2.4
0 x 08	Coordinator realignment		X	7.3.2.5
0 x 09	GTS request			7.3.3.1
0 x 0a—0 x ff	Reserved			—

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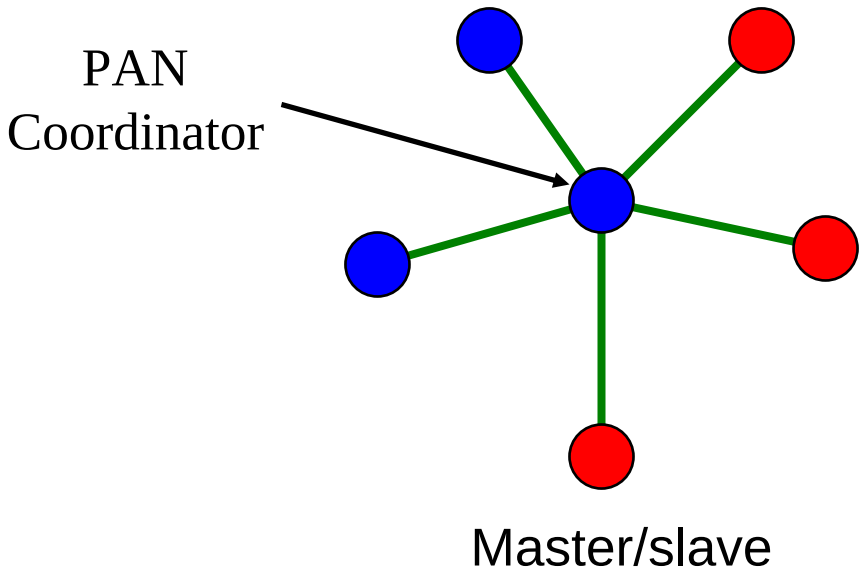

Full function device

Reduced function device

Communications flow

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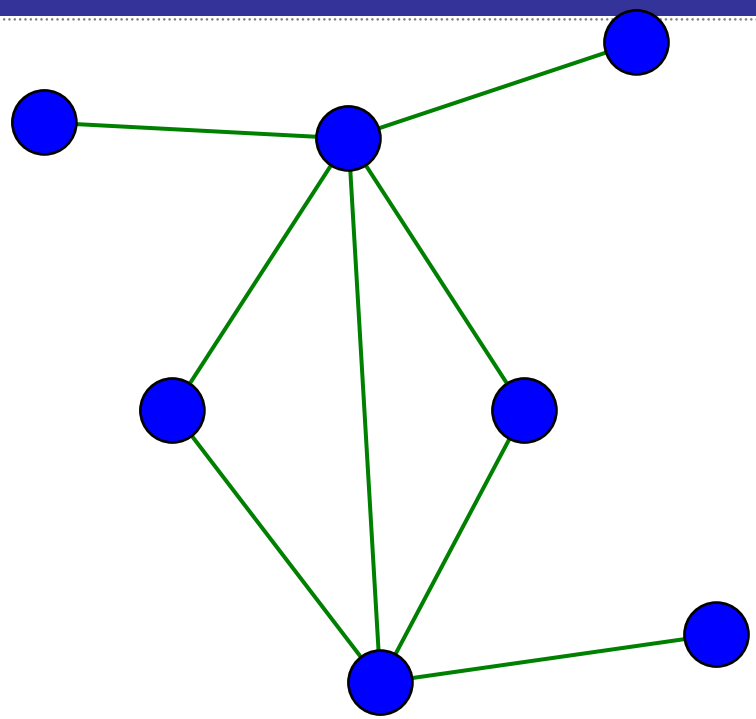
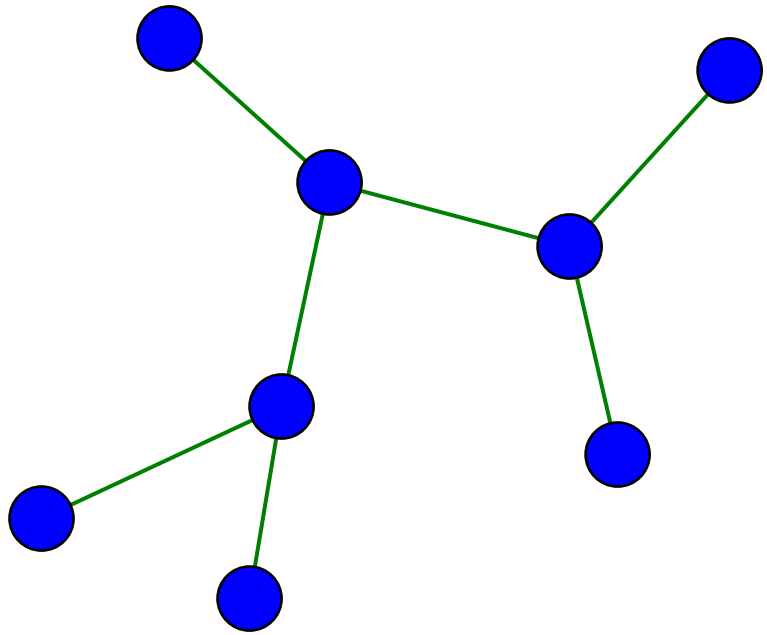


Point to point



Cluster tree

Full function device

Communications flow

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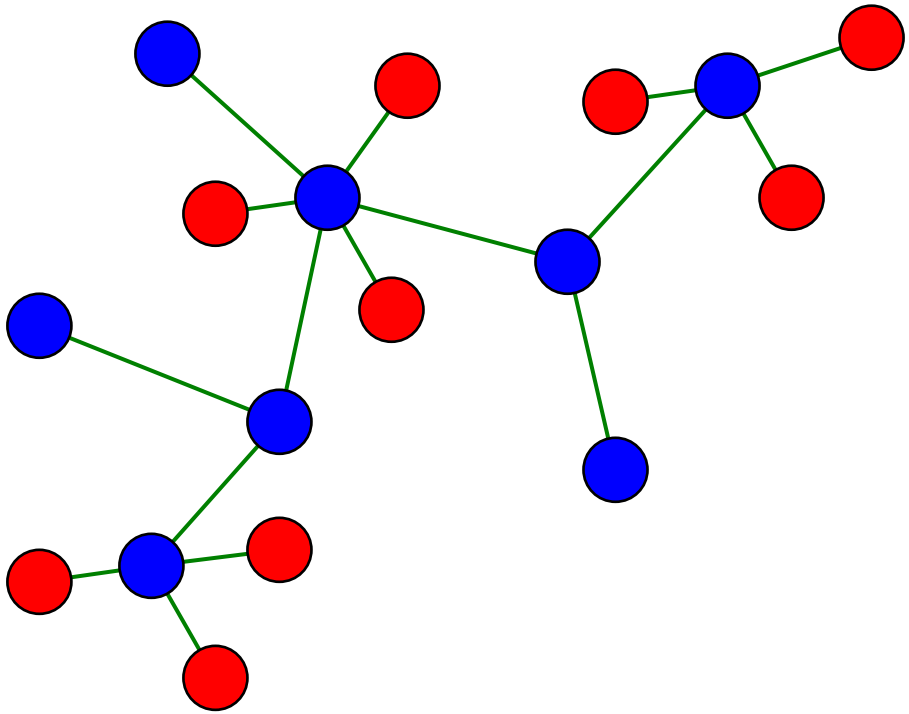

Clustered stars - for example, cluster nodes exist between rooms of a hotel and each room has a star network for control.

Full function device

Reduced function device

Communications flow

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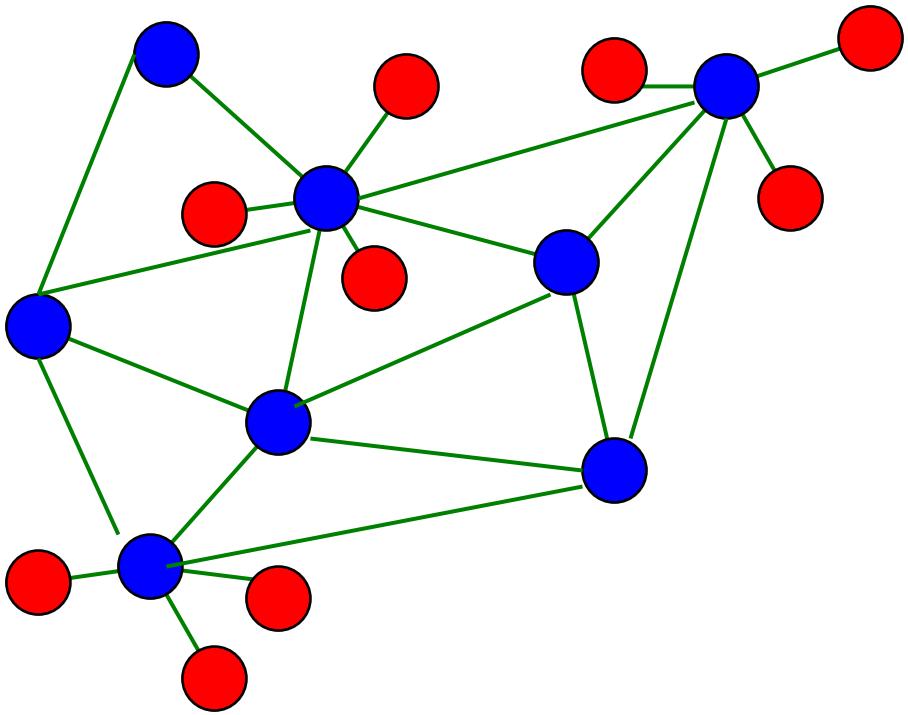

MESH

Full function device

Reduced function device

Communications flow

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- Relevant issues for Regulatory Testing
  - IEEE 802.15.4 MAC or proprietary MAC
    - For IEEE 802.15.4 MAC, ZigBee Alliance requires formal compliance with the specification
      - Currently: Ember Corporation, Chipcon AS, Freescale Semiconductors, Integration Associates, Helicomm Corporation have conforming MACs
    - For non-IEEE 802.15.4 MAC, numerous niche market implementations
      - Point-to-Point and MESH applications
      - Some are bandwidth hoarding

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- Relevant issues for Regulatory Testing
  - IEEE 802.15.4 MAC
    - For IEEE 802.15.4 MAC, currently limited number of microcontroller implementations:
      - Atmel Corporation ATMEGA128
      - Freescale Semiconductor H08
      - Renesas Corporation M16C
      - Silicon Laboratories 8051

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- Relevant issues for Regulatory Testing
  - MARKET for IEEE 802.15.4 systems is LARGER than ZigBee market
  - ZigBee controls the IEEE 802.15.4 market

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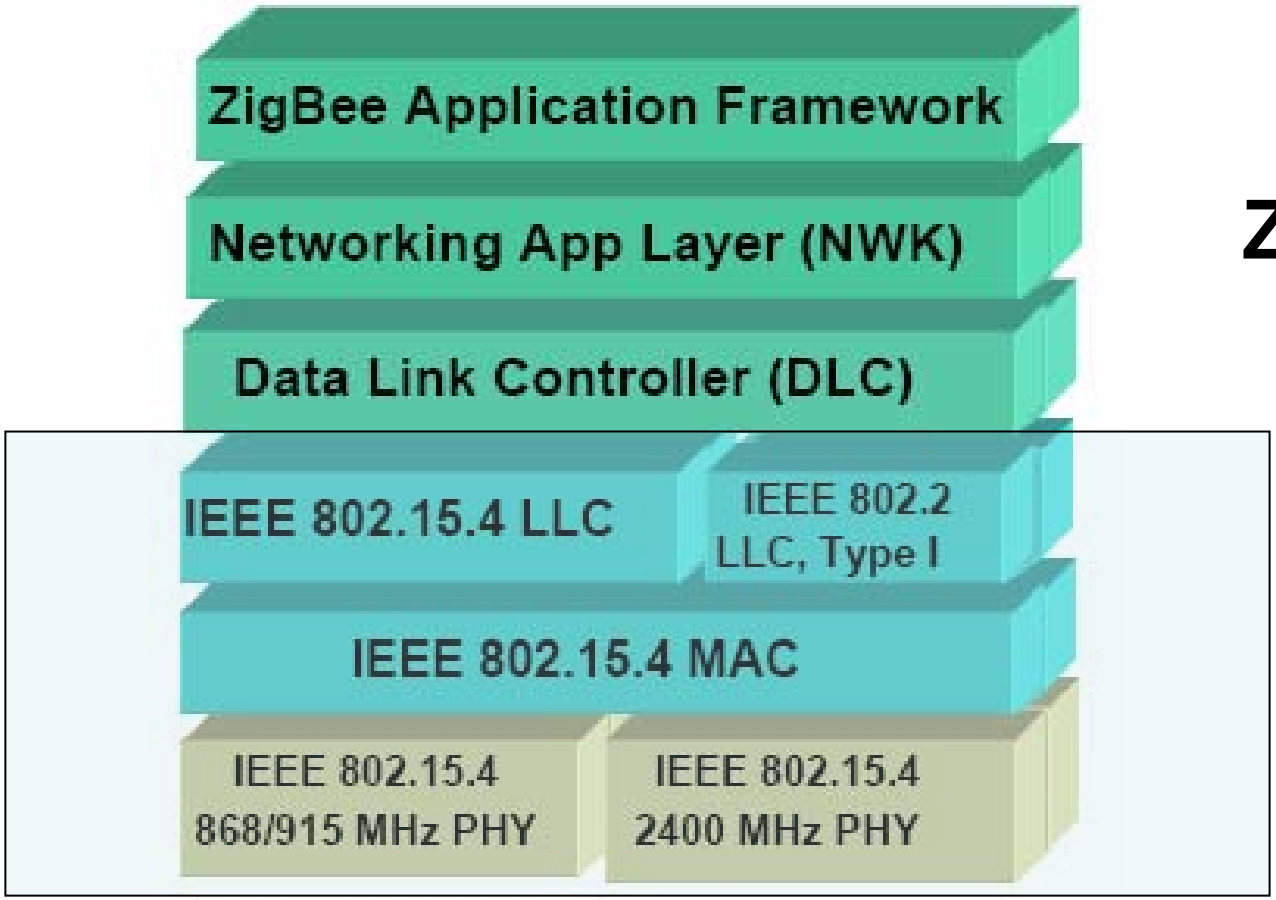

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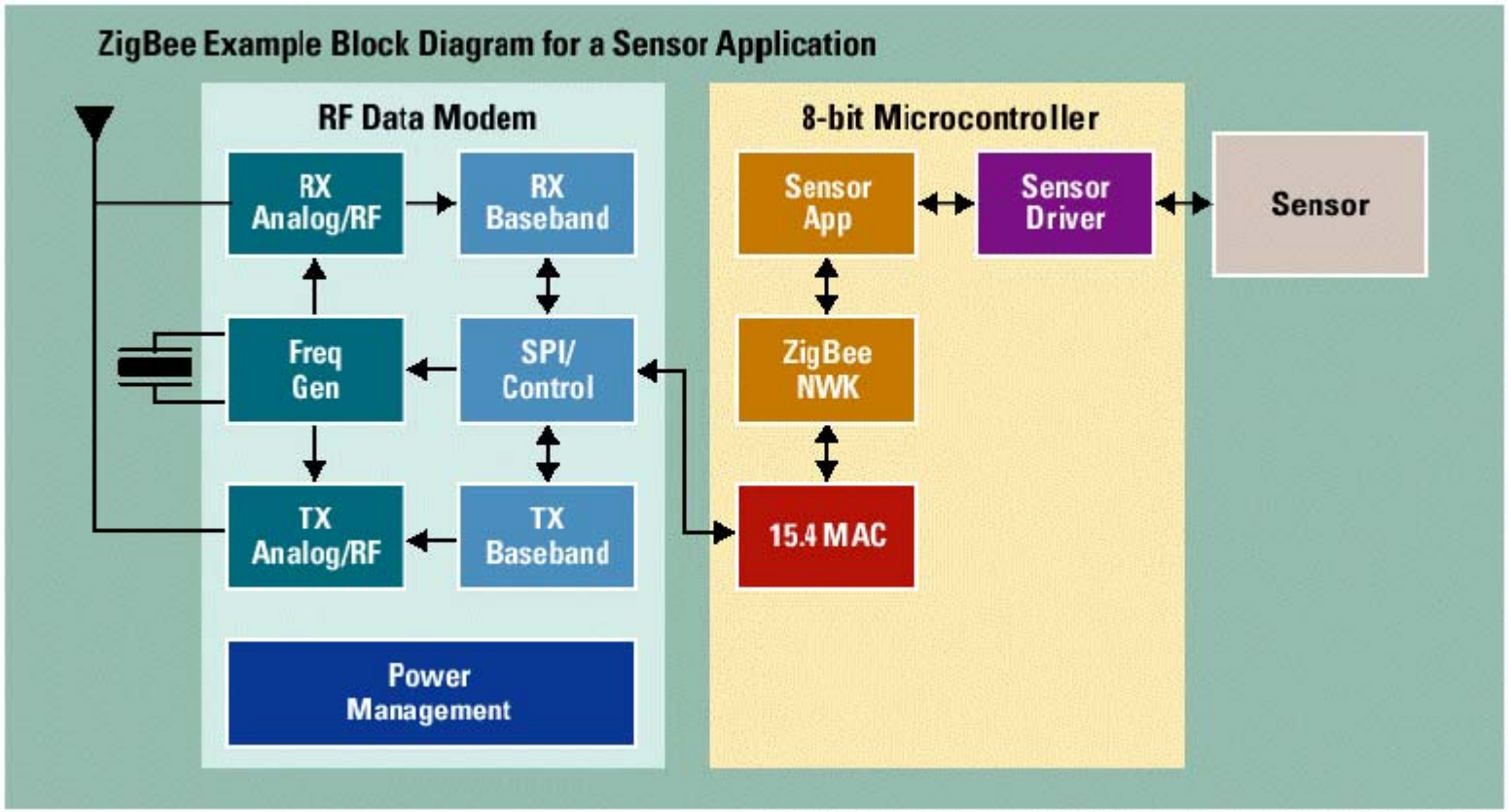

e.g. Freescale MC13192 radio

e.g. Freescale H08 CPU

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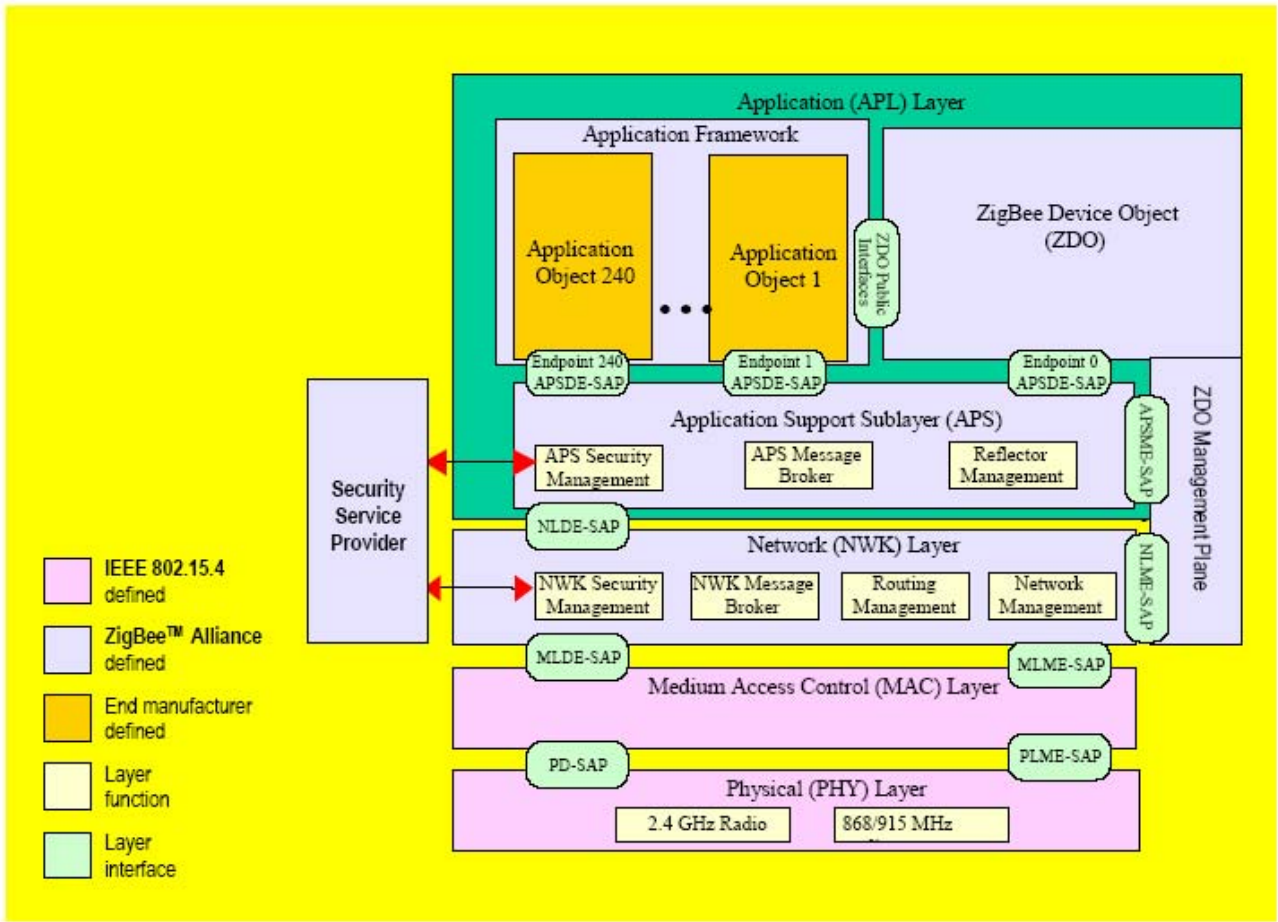

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Key Points

- ZigBee isolates the Application Layer (Application Framework) from the Network Layer and the MAC layer

- Devices talk to other Devices, without worrying about the MESH network underneath

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- What does the IEEE 802.15.4 PHY/MAC enable ZigBee to do?
  - Enables Networking Formation
  - Enables Communication between peer devices

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- What does the ZigBee enable IEEE 802.15.4 PHY/MAC to do?
  - Enables MESH
  - Enables HOPPING/RELAYING
  - Enables BRIDGING
  - Enables ROUTING
  - Enables Self-mending of ROUTES
  - Enables Common Application Framework

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- ZigBee frees the application developer from details of wireless communication
- Common framework (“Application Framework”) defined that abstracts the requirements of interfacing with the Application Support Sublayer (APS)
- API to protocol stack specific to individual manufacturers

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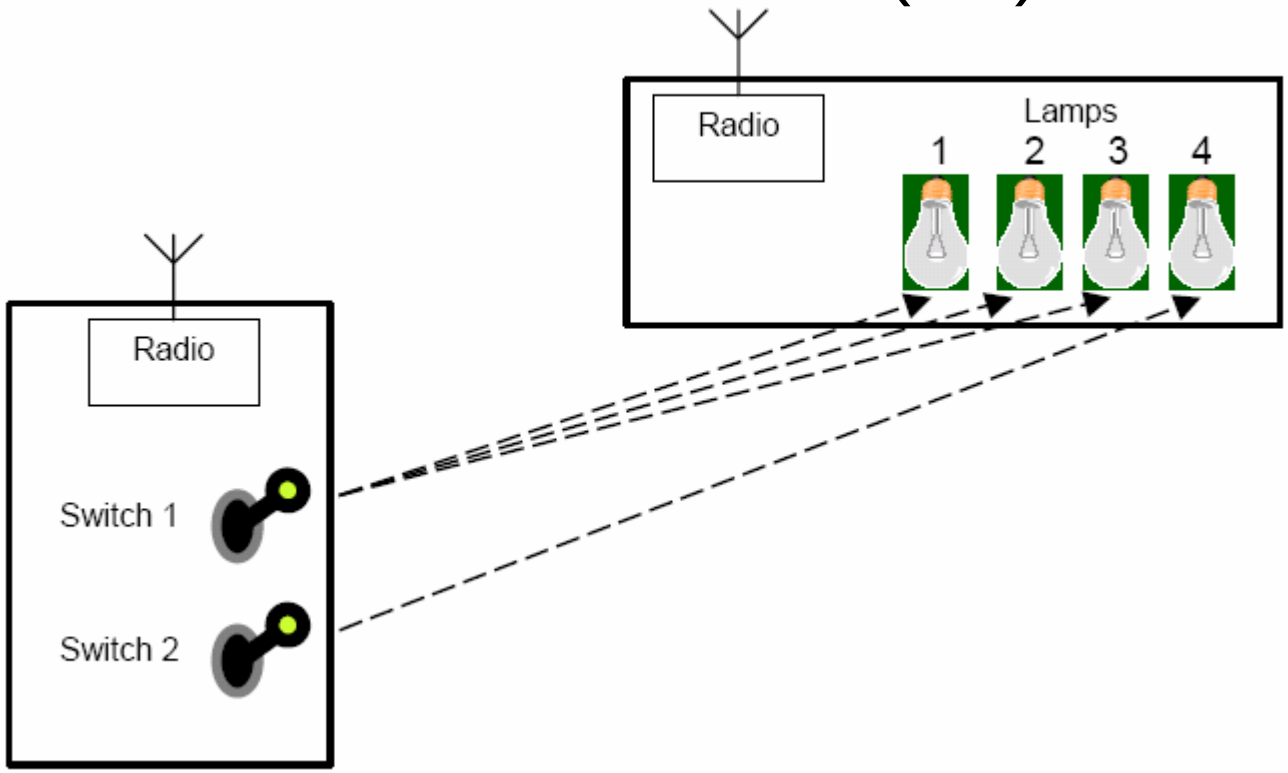
HOME AUTOMATION (HA) PROFILE



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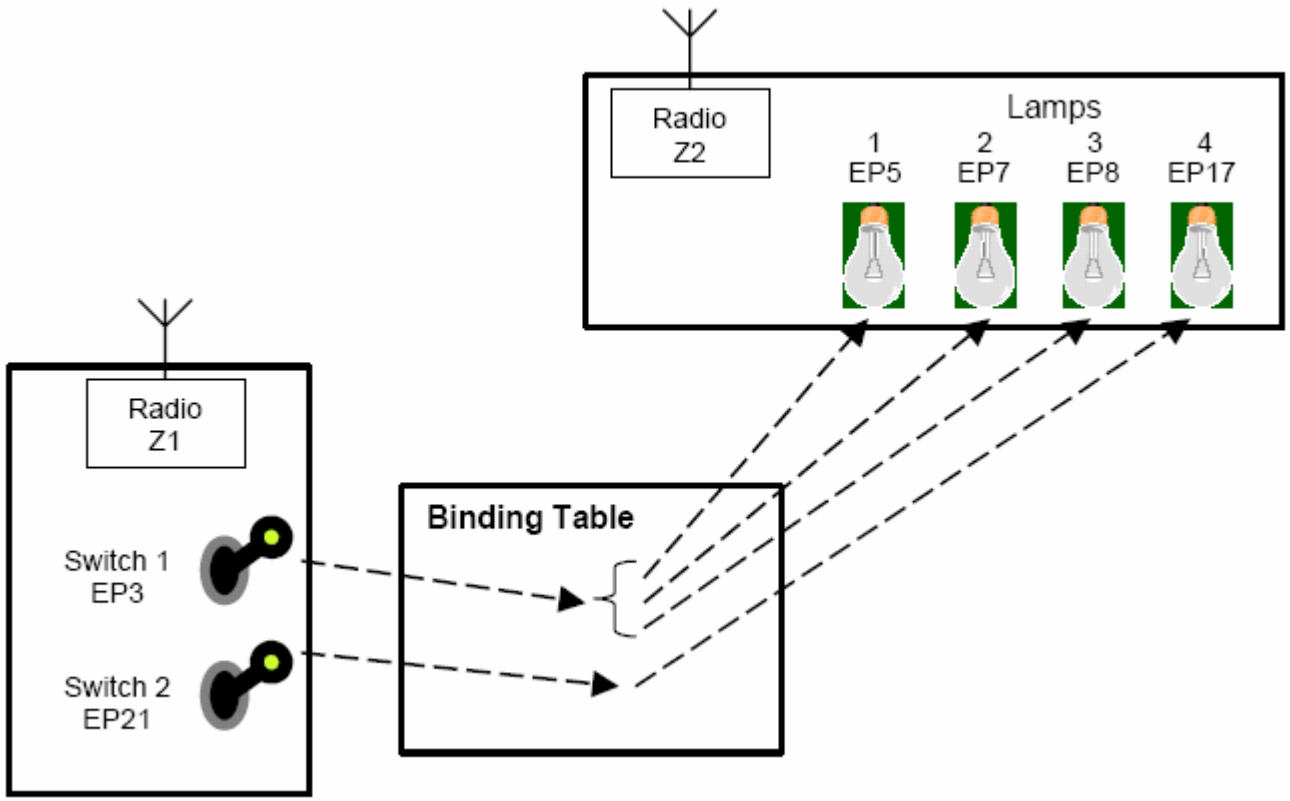

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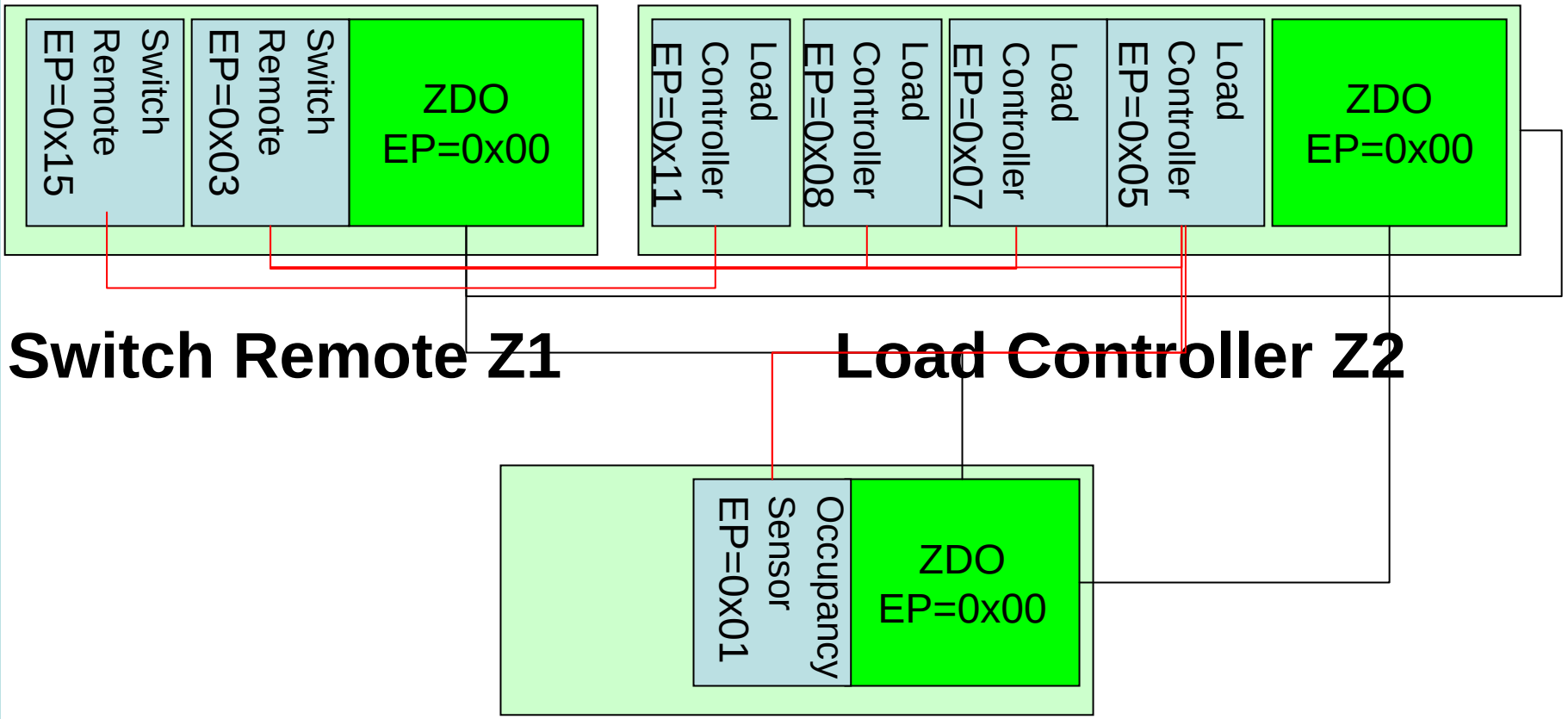

Switch Remote Z1

Load Controller Z2

Occupancy Sensor Z3

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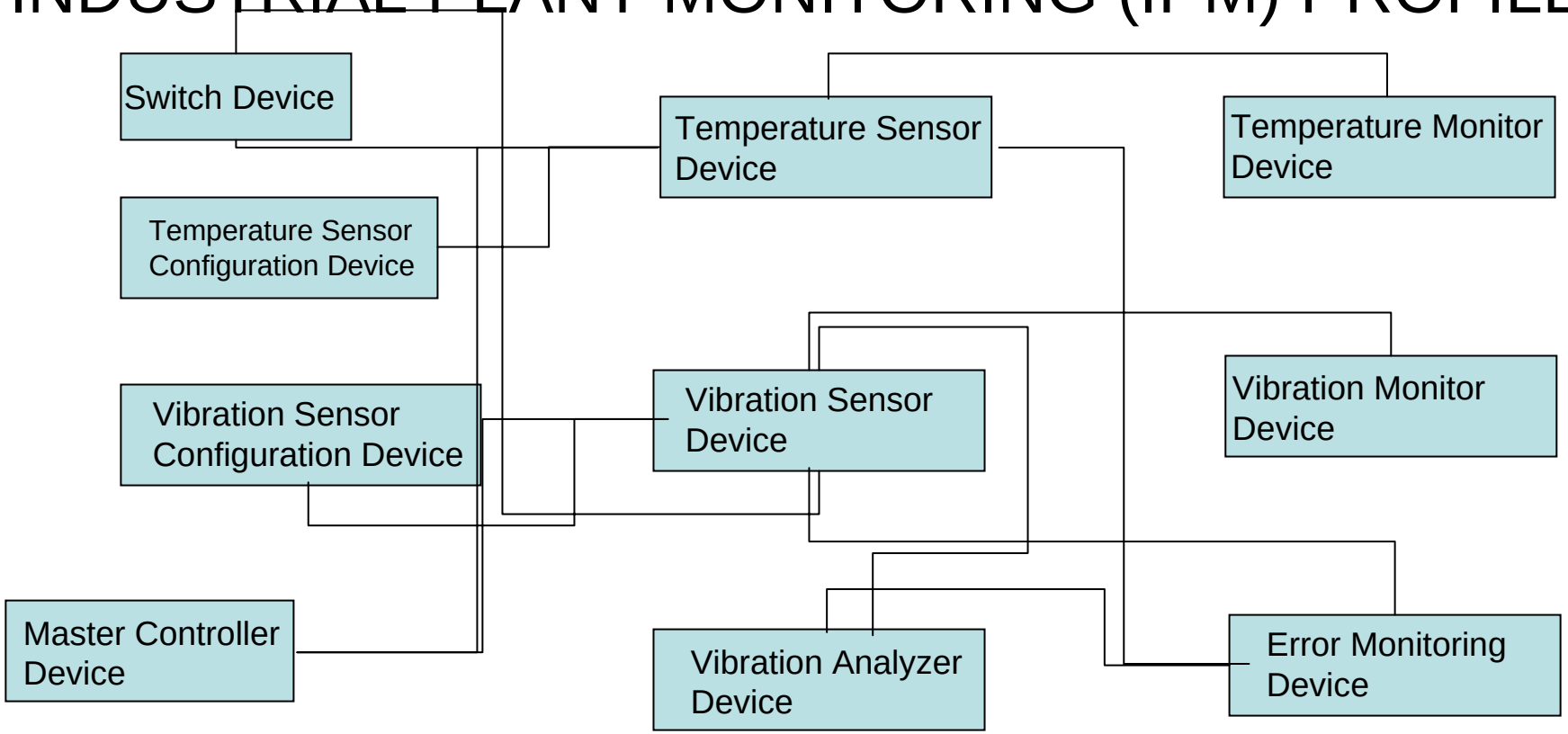
INDUSTRIAL PLANT MONITORING (IPM) PROFILE



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- What are ZigBee Application Profiles?
  - Grouping of specific Devices that interact within tha Application Profile grouping
  - Multiple manufacturers will develop Devices for specific Application Profiles
    - E.g.: Honeywell and Danfoss may build ZigBee IPM Profile compatible temperature sensors.
    - Other Profiles: HVAC, HCL, etc.

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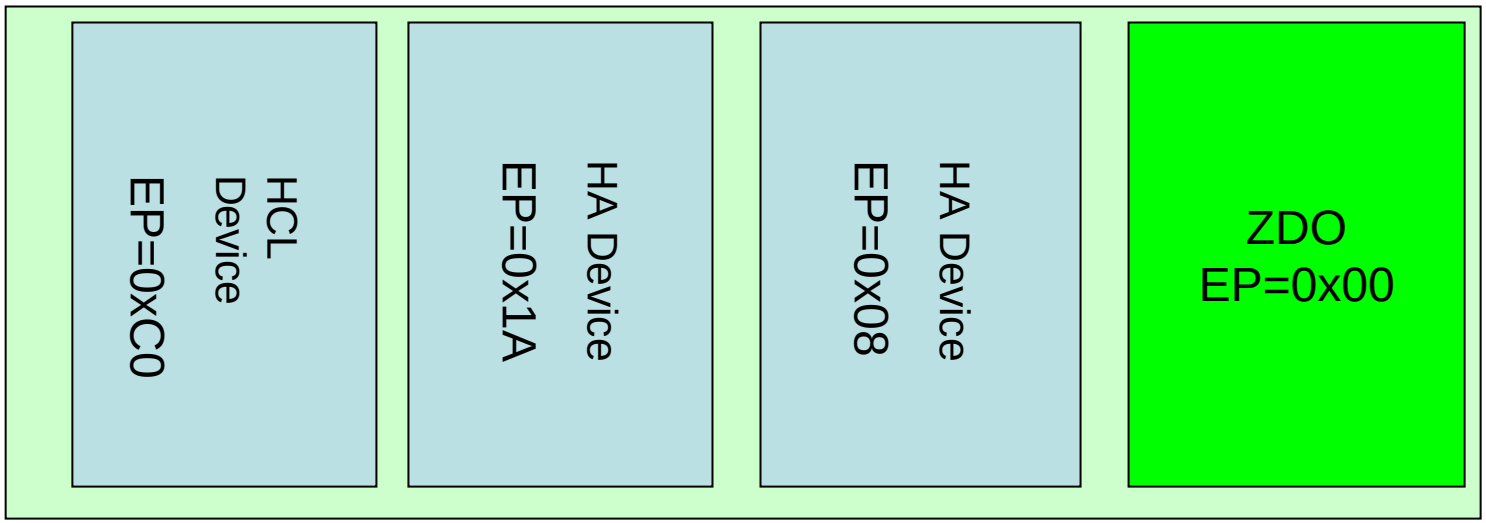
Multiple Application Profiles may coexist on one ZigBee Device



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Device / Service Discovery / Binding Management / Networking Management / Node and Security Functions

ZigBee Device Object

Specific Device from ZigBee Device Application Profile

One Device: ZDO Part of ZCP

-NWK Address Request
-IEEE Address Request
-Node Description Request
-Power Description Request
-Endpoint Device Bind Request
-Bind Request
-Unbind Request
-Network Remote Discovery
-Channel LQI
-Binding Table Information
-Leaving Network
-Discovery
-Joining a PAN
-Leaving a PAN
-Security Key
-Security Authentication
-etc….

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- ZigBee Compliant Platform (ZCP)
  - Official Certification given to hardware/software combinations
  - Contains the IEEE 802.15.4 Radio
  - Contains the IEEE 802.15.4 MAC on a specific microcontroller
  - Contains the ZigBee Protocol Stack, including the ZDO, APS, NWK, SEC and API to Application Framework

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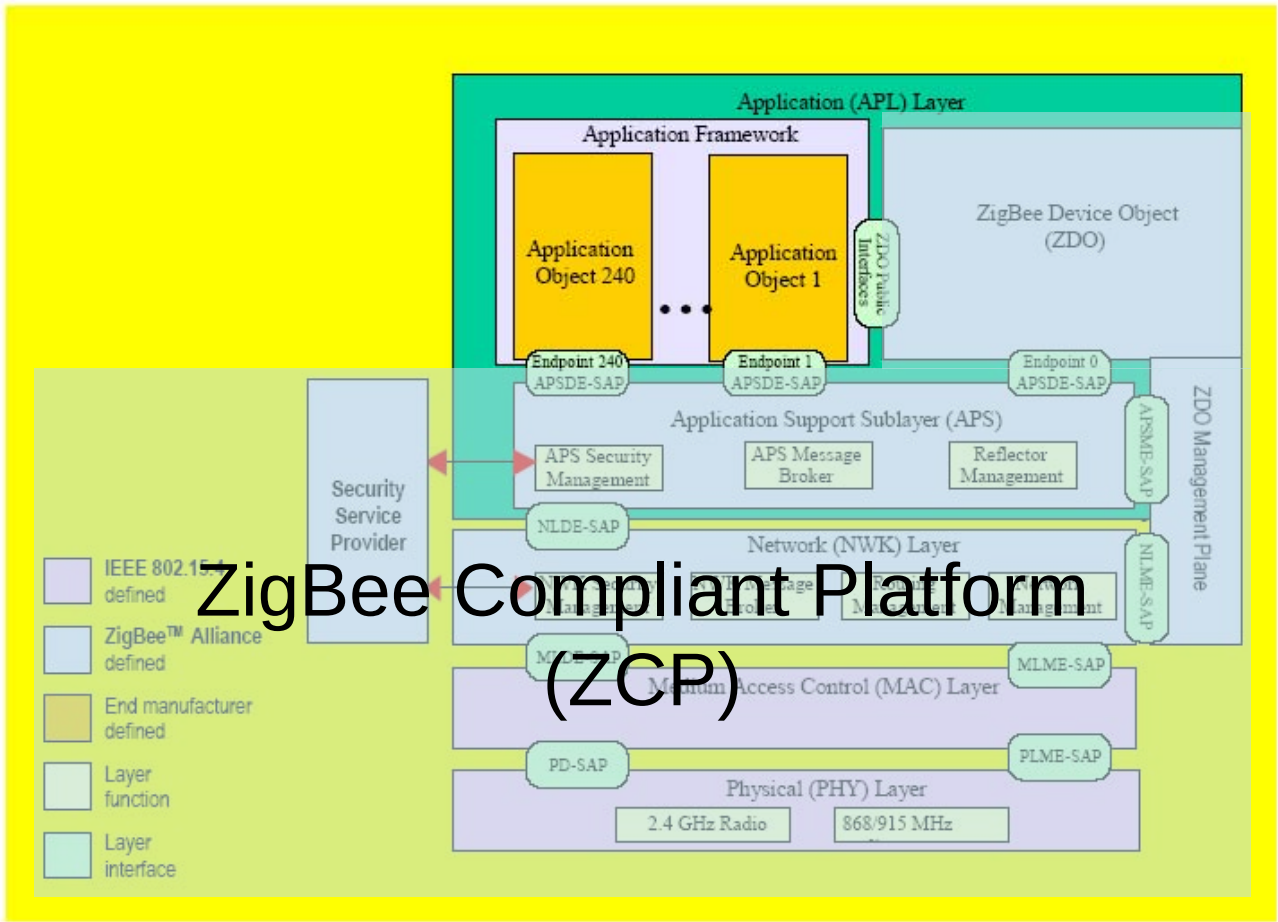

ZigBee Compliant Platform (ZCP)

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- Currently Four ZCP manufacturers:
  - Ember Corporation
  - Chipcon AS
  - Freescale Semiconductors
  - Integration Associates

- All ZigBee products will be based on existing ZCP

- Relevant issues for Regulatory Testing
  - ZCP does not provide direct control of IEEE 802.15.4 radio
  - Most likely, special code build necessary
  - Special build will not function as a ZigBee device, but simply as an IEEE 802.15.4 radio
  - Only ZCP manufacturers can provide special builds
  - Actual ZigBee products will have limited I/F

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Q & A

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